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ABSTRACT

The validity of the word attack skill tests of the Wisconsin Design for Reading Skill Development is studied at six grade levels by an investigation of the relationship of these to several widely known reading achievement tests. The basic notion is that reading mastery scores derived from the diagnostic tests should be positively related to the achievement scores in a simple manner. The requirements implied by this notion are specified and the procedures for examination of data to determine extent of agreement are described. The results of the analysis indicate that the requirements are fulfilled in all but one case. The main conclusion is that the validity of the word attack subtests is supported by the data. (Author)

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STUDY OF RELATIONSHIPS OF READING MASTERY LEVEL TO GENERAL READING ACHIEVEMENT TO VALIDATE DIAGNOSTIC READING TESTS

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The Wisconsin Design for Reading Skill Development has been developed to aid the operation of a program of individually guided reading instruction in grades K-6 (see Otto and Askov, 1970). One part of the Design includes a set of criterion-referenced tests of Word Attack skills at each of four difficulty levels. In previous work the adequacy of each of the individual subtests in the collection was examined by item analyses and determination of Hoyt internal consistency reliabilities (Fischbach, Harris, and Quilling, 1970). These results indicated that the subtests generally fulfilled the criteria that had been established for that phase of the evaluation. The validity of the subtests for the purposes which led to their construction is the basic content validity of the items used to construct them.

The present study was designed to examine the adequacy of the entire set of subtests in a different manner. An underlying concept of the Design is the notion of a part-whole relationship between specific reading skills

and general reading proficiency. An implication is that general reading achievement can be increased by instruction directed toward development of specific reading skills. The subtests permit teachers to determine which skills their students have not mastered so that instruction may be appropriately directed. If this concept is valid and if the subtests are good measures of the important skills, then it should be possible to demonstrate the part-whole relationship empirically. Thus, an examination of the relationship between scores on the subtests and fair measures of general reading level should provide information concerning both the validity of the underlying concept and the adequacy of the subtests as measures of the specific skills.

The first task was to operationalize this concept so that it would be used to guide the analysis of data. This might be done in several ways. The way selected is one of interest because it emphasizes the dichotomy between mastery and non-mastery of skills. It was decided to use criteria already in use to determine whether a skill had been mastered, to count the number of skills mastered, and finally to call the result the mastery score. The part-whole relationship described before can be examined by determining what relationship, if any, this mastery score has to general reading levels.

If all the skills measured by the subtests are important for reading proficiency, if they are of nearly equal importance (so that no one has a dominant effect), and if the relationship is a positive one, one should expect this relationship to take a relatively simple form. The regression of reading achievement scores on mastery score should take the form of a

"simple" polynomial function which is monotonically increasing over the range of possible mastery scores. The type of relationship expected would be graphically depicted as a smooth curve - or simply a line - which is predominantly linear with a positive slope which changes gradually, if at all. This would be a polynomial of degree two at most although this cutoff is somewhat arbitrary as the acceptability would depend on several factors. The objectives of the study are three-fold: at each level of difficulty to determine (1) if level of reading proficiency is related in any way to the number of Word Attack skills mastered; (2) if so, to determine the degree of the polynomial equation describing that relationship; and (3) to determine if the form of the relationship is consistent with that conceptualized.

METHOD

Data for the study were obtained for subjects in grades one to six from the regular fall testing program of a school using the Wisconsin Design. Each grade or unit received the level of Word Attack subtests deemed most appropriate for initial diagnostic purposes for the children involved. The school supplied grade equivalent scores on two or more standardized reading achievement tests for each subject. Scores on the Metropolitan Reading Readiness Test were used for grade one. The number of students, the level of Word Attack, the number of Word Attack subtests, and the reading achievement tests used are shown for each grade or unit in Table I.

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Insert Table I about here
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Needless to say, the results of this analysis could well be specific to the particular school population used, to relationships existing at the beginning of the school year before most instruction had occurred, and to the particular reading achievement tests used. Moreover, the relationships described below cannot be regarded as more than descriptive for the data for this study.

MASTERY SCORING

The criterion for mastery on a Word Attack subtest was that 80% or more of the items on the subtest were answered correctly. The number of skills so mastered was determined and this was the mastery score for a student, the "independent" variable for the study. It is evident that the same mastery score could be obtained in several different ways.

ANALYSIS

The data for each level of difficulty of Word Attack was analyzed independently of the other levels with one exception. The exception, at Level B, occurred because the grade three children involved were given only three of the four reading achievement tests given to the grade two children. In this case the data for each grade is analyzed separately. Three grade groups received Level D Word Attack but each had received different forms of the same achievement tests. The grade effects (which were significant

at the .001 level on both dependent variables), which are confounded with form effects, were "removed" from the model before effects due to regression. Homogeneity of regression for the three grade levels was examined by appropriate multivariate analysis of variance tests and the null hypothesis of no difference in the regressions among the three grade groups on either or both of the two reading achievement tests did not have to be rejected ($p < 0.36$). Except for the differences just noted and the fact that the number of dependent variables as well as the number of levels of mastery score varied among the analyses, all of the analyses followed the same procedures and will be described collectively. All computations were done using the multivariate analysis of variance program by Finn (1968).

Each mastery score defines a distinct level or "cell" in an appropriate one-way layout for multivariate analysis of variance. The first step was to compute the standard deviations on each dependent variable for each of these cells. These were inspected as a check of the assumption of homogeneity of variance (covariances were not checked). Gross violations of this assumption could indicate violation of the assumed equality of the mastery score units which, in turn, could mean a gross departure from the assumed approximate equality of importance of the skills. The results of this examination did not require rejection of the assumption of homogeneity of variances.

The next step was to test the null hypothesis of no relationship between reading achievement and mastery score on any measure of reading achievement by a multivariate analysis of variance test requiring significance at the .05 level for rejection. Only if this null hypothesis - which is equivalent to the hypothesis that the degree of the regression is zero -

were rejected, would the analysis continue. It might be noted that an incidental consequence of this is to ensure that the "family" or "experimentwise" Type I error rate (see Miller, 1966) is no greater than .05 per analysis.

In the next step the degree of the polynomial regression was determined using orthogonal polynomial contrasts and a procedure adapted from one proposed by Anderson (1962). A working assumption for this procedure is that if the polynomial has a nonzero coefficient for a term of degree k, then the polynomial is of degree k and all coefficients of degree k-1 or less are presumed to be nonzero as well. All tests require significance at the .05 level for rejection of null hypotheses. The first hypothesis tested is that coefficients of all terms of degree three or higher for all acheivement scores are zero. If this hypothesis is rejected, e.g., if the polynomial is cubic or greater order, the validity of the concept is tentatively rejected unless other evidence overrides this result. If that hypothesis is not rejected, then hypotheses that the quadratic and linear coefficients, respectively, are zero are tested in sequence to determine the degree of the polynomial (if it should happen that the linear coefficients are found to be zero, the analysis is terminated). After this the coefficients for the best-fitting model are estimated. The estimated achievement scores at each mastery score are obtained and plotted in the form of curves along with actual mean values. If the pattern of deviations from predicted values does not suggest lack of fit and if the curves or lines reveal monotonically increasing relationships of the form expected, the validity of the concept would be said to be supported by the data of this study.

RESULTS

Significance levels actually attained for the various tests of multivariate regression hypotheses are shown in Table II. In all cases the hypothesis of no relationship must be rejected. In four of the five cases the degree of the polynomial was found to be two or less, and in three of the five cases a linear model was found to be adequate. The graphs of best fitting models and observed values are shown in Figures 1 to 5.

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Insert Table II about here
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Observed and predicted mean reading achievement score at each mastery score for each reading achievement test and each level of difficulty are shown in Table III. These are the values plotted in Figures 1-5.

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Insert Table III about here
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The one case where a cubic or higher order polynomial appears necessary is grade 2 students on Level B Word Attack. Interestingly, a linear model was found to be fairly adequate for grade 3 students on Level B Word Attack, although the number of students - and hence the power of tests - was less in the latter case. In many respects the relationships, when plotted as in Figures 2 and 3, appeared remarkably similar for both groups. The largest coefficients in both cases are the positive ones for the linear terms and reading achievement does tend to increase with mastery level. Because the quadratic and cubic coefficients are not large in the grade 2 case the graph in Figure 2 shows the best fitting lines

rather than curves. When viewing these graphs one should note that the deviations from the predicted values are statistically significant. Some of the larger deviations occur for the four highest mastery scores where the numbers of subjects are small (see Table III for actual values).

When the reading tests were examined individually using univariate F-ratios it was found that the deviations from second degree polynomial regression were large enough to be statistically significant for Word Meaning ($p < .011$) and Paragraph Meaning ($p < .005$) but not for Vocabulary ($p < .09$) or Word Study ($p < .81$). However, this is not strong evidence of good fit to a second or first degree polynomials for the latter two cases. But if the analysis had been continued in these cases, individually, the hypotheses that the quadratic coefficients are zero would not be rejected ($p < .27$ and $p < .72$, respectively) but the comparable hypotheses about linear coefficients would be ($p < .001$ in both cases).

A second-degree polynomial is necessary for Level C Word Attack for Grade 3 students. The relationships of mastery score to the three dependent variables was found to be monotonically increasing with one minor exception. The exception occurs for Word Study where the predicted value decreases from 1.88 at mastery score 0 to 1.85 at 1 but the predicted values increase with mastery score from that point on. The graphs in Figure 4 and the predicted values for this case in Table III do presume that the regression is that of a second degree polynomial for all three dependent variables. Additional analysis reveals that if the hypothesis that the coefficient of the second degree term is zero had been tested for each dependent variable, this hypothesis would be rejected only in the case of Word Study ($p < .01$) but not for Word Meaning ($p < .054$) or for Paragraph

Meaning ($p < .17$). However, this does not preclude the possibility that some linear combination of the second degree coefficients for the latter two variables is non-zero.

A linear model was found to be adequate for Level A for Grade 1 students. As noted in Table II the null hypothesis that the linear coefficients for all six Metropolitan Readiness scores are zero must be rejected. Separate univariate analyses indicate positive coefficients for five subtests ($p < .02$ in all cases). For one, Word Meaning, the hypothesis that the coefficient is zero cannot be rejected ($p < .41$) although the estimated coefficient is positive in that case, too.

The best fit to linear regression was found at Level D Word Attack for grades 4, 5, and 6. Moreover, the slopes of the best fitting lines were steepest in this case.

DISCUSSION

The results of this analysis generally provide support for a basic notion of the Wisconsin Design that general reading level is related to the number of specific reading skills mastered. However, the results here must be viewed as tentative and should be interpreted in the context of the limitations of the data used. One interesting result, which may of course be the result of unknown factors, is the tendency for the expected relationship to be supported more strongly at the higher grade levels. This may reflect the cumulative results of previous instruction or that reliable measurement of general reading achievement is more difficult for less advanced students.

These results do not "prove" the validity of the Word Attack subtests nor the practical utility of the Design. Nor could this be expected with any study of this type. The basic test of the validity of the subtests is the content validity which was established before this study, and the utility of the Design is now being tested in a carefully planned study for that purpose. However, the practical import of this study is that with relatively low cost it was possible to check for gross deficiencies and thus avoid the needless expense of large scale studies in the event of negative findings.

Table I Number of Subjects and Tests Used by Grade

Grade	Number Students	Word Attack Subtests: Difficulty Level	Word Attack Subtests: Number	Reading Achievement Tests
1	68	A	6	Metropolitan Reading Tests, Form A (Word Meaning, Listening, Matching, Alphabetizing, and Copying)
2	56	B	11	Stanford Achievement Test Primary 1, Form W: (Word Meaning, Paragraph Meaning; Vocabulary, Word Study Skills)
3	31	B	11	Stanford Achievement Test Primary 1, Form W: (Word Reading, Paragraph Meaning, Word Study)
3	50	C	13	Stanford Primary 2 Form W: (Word Meaning, Paragraph Meaning, and Word Study Skills)
Total 4-6	227	D	6	Stanford Achievement
4	81			Form W Intermediate 1
5	82			Form X Intermediate 1
6	64			Form W Intermediate 2 (Word Meanings and Word Study Skills)

Table II Summary of Results of Analysis of Variance for Regression of Reading Achievement Scores on Mastery Score by Word Attack Level

Source of Effect	Significance Levels Attained Word Attack Level and Grade				
	A	B		C	D
Grade	1	2	3	3	4-6
Between Mastery Scores - All components	.002	.001	.02	.001	.001
By Component					
Linear	.002*	.001	.001*	.001	.001*
Quadratic	.17	.09	.27	.02*	.90
Cubic & all higher	.60	.001*	.82	.44	.19
Number of dependent variables	5	4	3	3	2
Degrees of freedom per dependent variable	61	46	21	37	206**
Number of non-empty cells	7	10***	10***	13***	7
Number possible cells	7	12	12	14	7

* Indicates significance level of last hypothesis tested. Those appearing above these, are for reference only.

** 2 degrees of freedom used for grade effects and 12 for grade x mastery level effects.

*** Cells for which there were no subjects:
Level B Grade 2 - 2 empty cells were at two highest possible scores
Level B Grade 3 - 2 empty cells: one at lowest possible score and one at highest possible score
Level C Grade 3 - 1 empty cell at score 11 with score 12 as the highest possible score.

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Table III Predicted and Observed Mean reading Achievement Scores by Mastery Score by Word Attack Level of Difficulty

Level A for Grade 1 Students - These values are plotted in Figure 1

Mastery Score	No. of Subj.	Metropolitan Reading Readiness Subtests: Word Meaning Obs.	Word Meaning Pred.	Listening Obs.	Listening Pred.	Matching Obs.	Matching Pred.	Alphabetizing Obs.	Alphabetizing Pred.	Copying Obs.	Copying Pred.
0	2	8.00	8.42	4.50	7.35	3.00	3.34	1.00	3.07	0.50	1.51
1	3	10.67	8.63	9.67	7.90	4.33	4.37	8.33	4.77	1.33	2.48
2	6	10.00	8.84	8.67	8.45	6.83	5.40	5.67	6.48	2.67	3.44
3	8	7.62	9.04	8.38	9.01	6.88	6.44	7.63	8.18	5.25	4.41
4	19	9.05	9.25	10.32	9.56	6.42	7.47	10.16	9.89	6.42	5.37
5	19	8.84	9.46	9.53	10.11	8.47	8.50	11.26	11.59	5.68	6.33
6	11	11.00	9.67	10.73	10.66	10.36	9.54	13.64	13.29	6.91	7.30
Total	68	9.26		9.59		7.53		9.99		5.43	
Std. Deviation		3.13	----	2.82	----	3.34	----	3.84	----	3.81	----
Estimated											
Constant, μ		----	8.42	----	7.35	----	3.34	----	3.07	----	1.51
Slope, β		----	0.21	----	0.55	----	1.03	----	1.70	----	0.96
Stan. Error of $\hat{\beta}$		----	0.25	----	0.23	----	0.27	----	0.31	----	0.31

Each score is the mean number of items correct observed or predicted for the mastery score group. Predicted scores, $\hat{y}(x)$, are obtained from the equation $\hat{y}(x) = \hat{\mu} + \hat{\beta}x$ using the estimated values given and where x is the mastery score.

Level B for Grade 2 Students - These values are plotted in Figure 2

Stanford Achievement Test Primary 1

Mastery Score	No. of Subjects	Word Meaning Obs.	Word Meaning Pred.	Paragraph Meaning Obs.	Paragraph Meaning Pred.	Vocabulary Obs.	Vocabulary Pred.	Word Study Skills Obs.	Word Study Skills Pred.
0	11	1.34	1.31	1.47	1.32	1.54	1.56	1.45	1.42
1	12	1.53	1.49	1.47	1.48	1.71	1.76	1.59	1.65
2	5	1.70	1.66	1.64	1.63	1.80	1.96	1.86	1.87
3	10	1.80	1.83	1.67	1.79	2.32	2.16	2.15	2.10
4	5	1.86	2.00	1.68	1.94	2.24	2.36	2.40	2.32
5	4	1.85	2.17	1.83	2.10	3.10	2.55	2.33	2.55
6	4	2.48	2.34	2.30	2.26	2.38	2.75	3.00	2.78
7	1	3.60	2.52	3.10	2.41	4.40	2.95	2.80	3.00
8	3	2.50	2.68	3.23	2.57	2.80	3.15	3.33	3.23
9	1	3.20	2.86	1.90	2.72	2.90	3.35	3.00	3.45
10	----	----	3.02	----	2.88	----	3.54	----	3.68
11	----	----	3.18	----	3.03	----	3.74	----	3.90
Total	56	1.79	----	1.75	----	2.11	----	2.05	----
Standard Deviation		0.30	----	0.34	----	0.58	----	0.45	----
Estimated									
Constant, μ		----	1.31	----	1.32	----	1.56	----	1.42
Slope, β		----	0.172	----	0.156	----	0.198	----	0.226
Stan. Error, $\hat{\beta}$		----	0.016	----	0.018	----	0.032	----	0.025

Each score is the mean grade equivalent score observed or predicted for the mastery score group. Predicted scores, $\hat{y}(x)$ can be obtained from the equation:

$$\hat{y}(x) = \hat{\mu} + \hat{\beta}x$$ using the estimated parameters given and where x is the mastery score. Deviations from these predicted values are statistically significant.

Level B for Grade 3 Students - These values are plotted in Figure 3

Stanford Achievement Test Primary 1

Mastery Score	No. of Subjects	Word Meaning Obs.	Word Meaning Pred.	Paragraph Meaning Obs.	Paragraph Meaning Pred.	Word Study Obs.	Word Study Pred.
0	0	----	1.55	----	1.64	----	1.34
1	4	1.75	1.69	1.92	1.77	2.02	1.61
2	5	1.96	1.84	1.90	1.89	1.84	1.87
3	3	1.80	1.98	1.97	2.01	2.00	2.14
4	4	2.10	2.12	2.00	2.13	2.32	2.40
5	1	1.80	2.26	2.10	2.26	2.20	2.66
6	2	2.15	2.41	2.00	2.38	2.00	2.92
7	3	2.67	2.55	2.60	2.50	2.83	3.19
8	3	2.73	2.69	2.57	2.62	4.47	3.45
9	3	2.93	2.83	3.13	2.75	3.00	3.71
10	3	2.97	2.98	2.73	2.87	4.53	3.98
11	0	----	3.12	----	2.99	----	4.24
Total	31	2.42	----	2.39	----	2.95	----
Standard Deviation		0.49	----	0.42	----	1.03	----
Estimated							
Constant, μ		----	1.55	----	1.64	----	1.34
Slope, β		----	0.143	----	0.123	----	0.263
Standard Error, $\hat{\beta}$		----	0.029	----	0.025	----	0.060

Each score is the mean grade equivalent score observed or predicted for the mastery score group. Predicted scores, $\hat{y}(x)$, are obtained from the equation

$\hat{y}(x) = \hat{\mu} + \hat{\beta}x$ using the estimated parameters given and where x is the mastery score.

Level C for Grade 3 - These values are plotted in Figure 4.

Mastery Score	No. of Subjects	Stanford Achievement Test: Word Meaning Obs.	Word Meaning Pred.	Paragraph Meaning Obs.	Paragraph Meaning Pred.	Word Study Skills Obs.	Word Study Skills Pred.
0	4	2.05	2.04	1.98	1.85	1.85	1.88
1	3	2.27	2.07	1.70	1.95	1.90	1.85
2	9	2.20	2.13	2.22	2.06	2.00	1.88
3	5	2.28	2.22	2.24	2.20	1.90	1.96
4	3	1.83	2.32	2.00	2.36	1.97	2.11
5	4	1.80	2.46	2.10	2.54	2.02	2.30
6	3	2.77	2.61	2.40	2.73	2.43	2.56
7	4	3.08	2.80	3.18	2.95	2.40	2.87
8	5	3.06	3.00	3.36	3.18	3.92	3.24
9	2	3.70	3.24	3.85	3.44	3.30	3.66
10	4	3.78	3.49	4.00	3.71	4.48	4.14
11	0	----		----		----	
12	4	3.75	4.08	3.981	4.31	5.00	5.27
Total	50	2.65	----	2.70	----	2.71	----
Standard Deviation		0.49	----	0.58	----	0.91	----
Estimated							
Constant, μ		----	2.04	----	1.85	----	1.88
Linear Coef. β_1		----	0.021	----	0.089	----	-0.055
Quadratic Coef. β_2		----	0.012	----	0.010	----	0.028
Stan. Error, $\hat{\beta}_1$		----	0.071	----	0.085	----	0.133
Stan. Error, $\hat{\beta}_2$		----	0.006	----	0.007	----	0.011

Each score is mean grade equivalant score observed or predicted for the mastery score observed or predicted for the mastery score group. Predicted score, $\hat{y}(x)$, are obtained from the equation $\hat{y}(x) = \mu + \hat{\beta}_1 x + \hat{\beta}_2 x^2$ using the estimated coefficients given where x is the mastery score.

Level D for Grades 4, 5, and 6 - These values are plotted in Figure 5.

Mastery Score	Grade	No. of Subjects			Stanford Achievement Test: Word Meaning Observed			Word Meaning Predicted	Word Study Observed			Word Study Predicted
		4	5	6	4	5	6		4	5	6	
0		18	13	4	3.86	3.38	3.19	3.46	2.43	2.69	2.64	2.56
1		29	12	9	3.92	3.77	3.52	3.90	3.42	3.22	3.46	3.30
2		19	27	14	4.22	4.24	4.37	4.35	4.09	3.71	4.24	4.03
3		9	13	22	4.57	4.82	4.75	4.79	4.40	5.63	4.49	4.77
4		3	10	10	5.00	5.84	5.75	5.25	5.68	5.05	5.70	5.51
5		2	6	4	5.50	5.38	5.89	5.68	6.88	6.13	5.89	6.24
6		1	1	1	3.90	7.11	5.19	6.13	6.08	9.00	7.91	6.98
Total		81	82	64	4.13	4.44	4.63	----	3.67	4.19	4.51	----
Std. Deviation (all grades)						1.06				1.30		
Estimated Constant, μ, averaged					----	----	----	3.46	----	----	----	2.56
Deviations from $\hat{\mu}$ by grade					-.10	-.12	0.21		-.28	0.00	0.28	
Slope, β								0.445				0.737
Standard Error, $\hat{\beta}$								0.051				0.062

Observed scores are observed mean grade equivalent scores corrected by the factors given in the row "deviations from $\hat{\mu}$ by grade" to remove grade effects. Predicted values, $\hat{y}(x)$, are given by the equation $\hat{y}(x) = \hat{\mu} + \hat{\beta}x$ where the estimates of parameters are those given and x is mastery score.

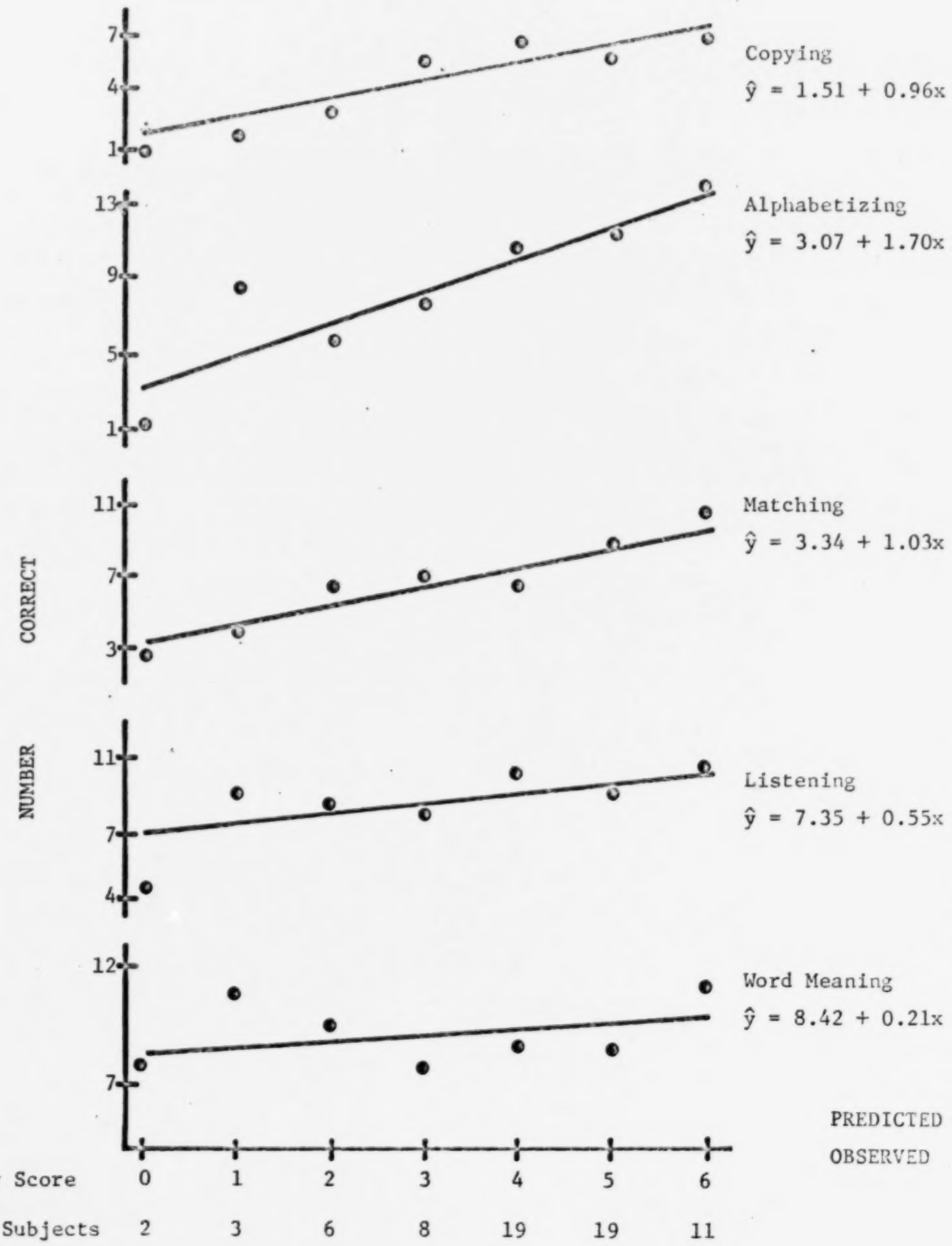


Figure 1 Metropolitan Readiness Mean Scores: Predicted and Observed by Mastery Score by Subtest for Grade 1 Students

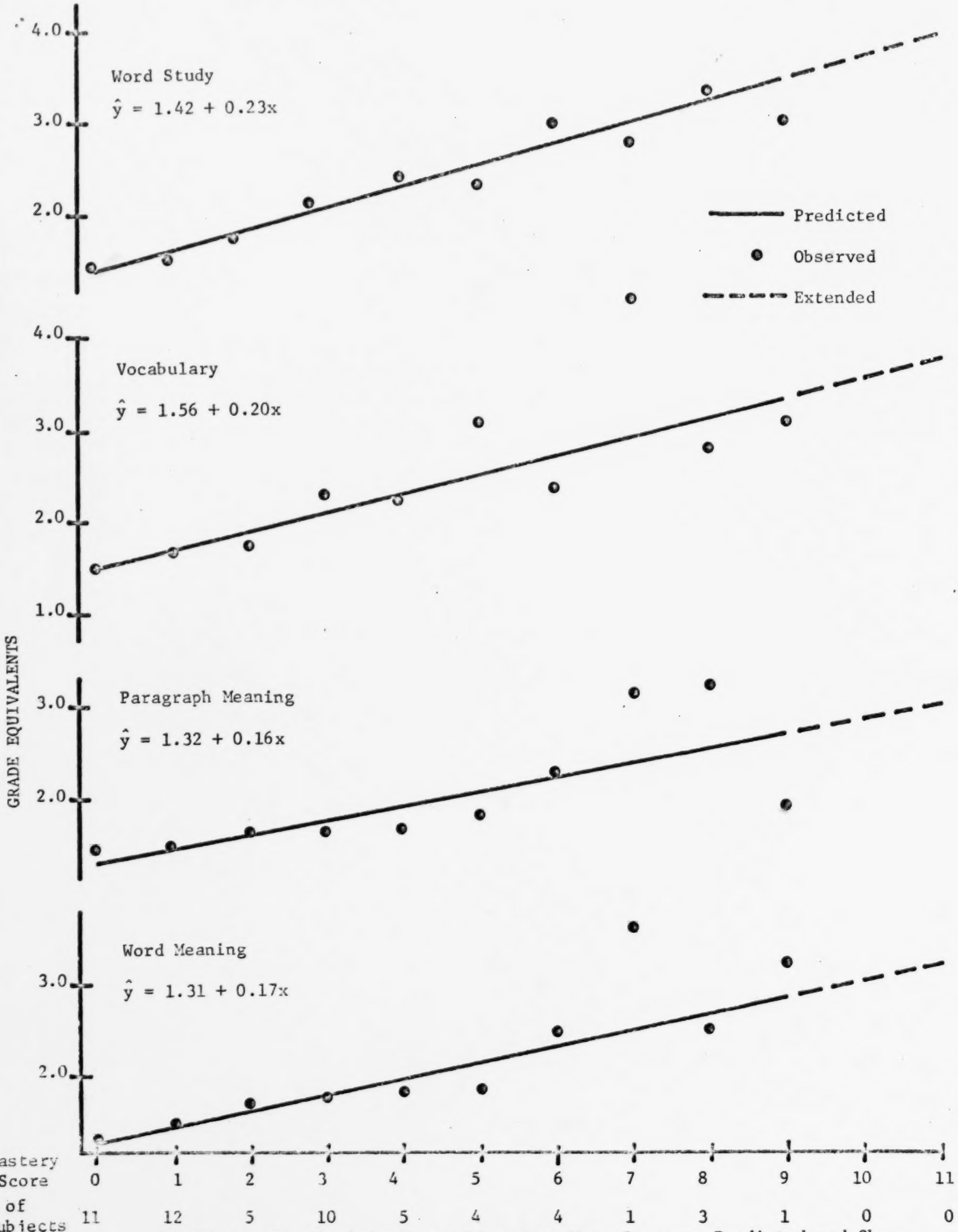


FIGURE 2: Stanford Reading Achievement Mean Scores: Predicted and Observed by Mastery Score by Subtest for Grade 2 Students

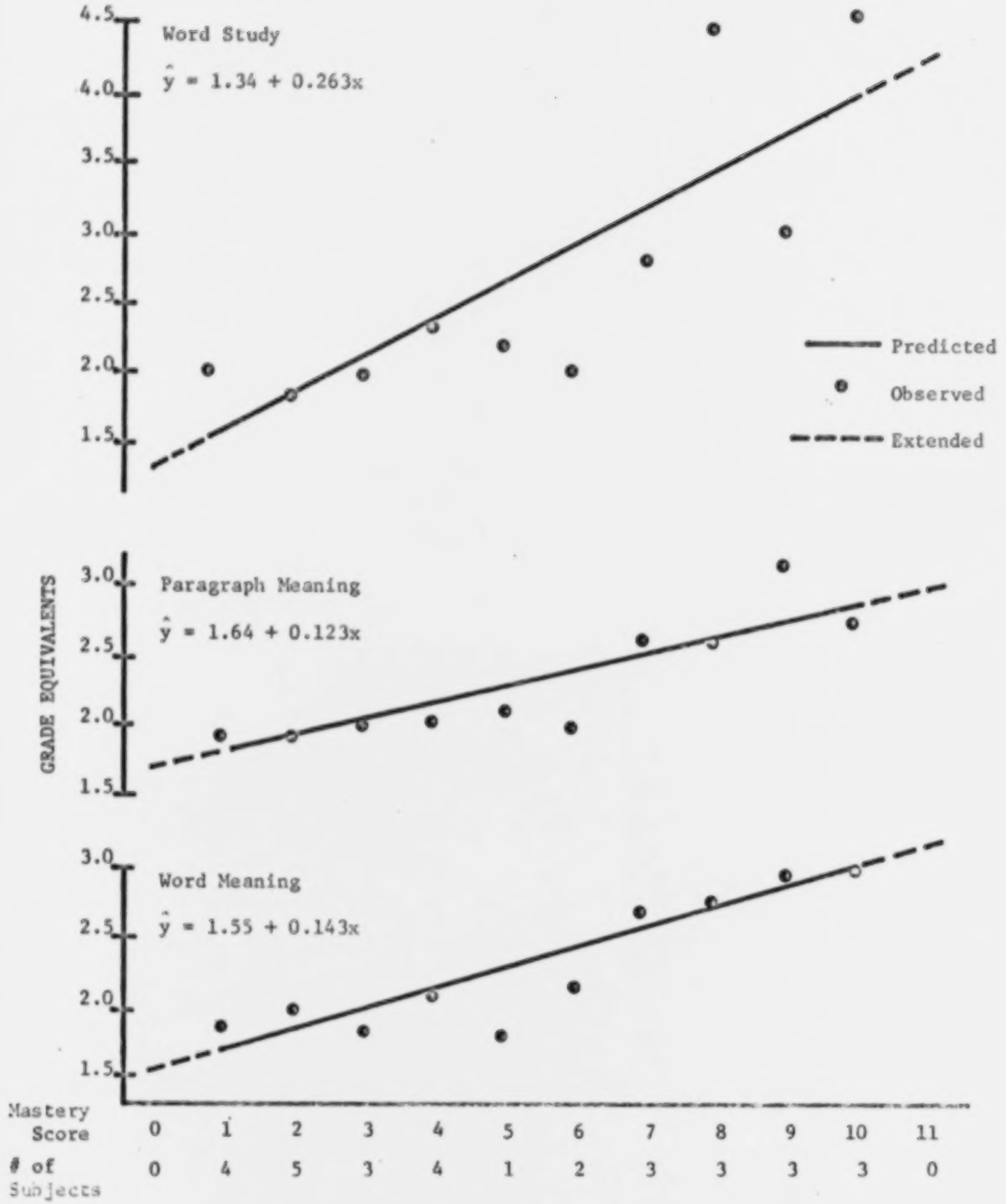


FIGURE 3: Stanford Achievement Test Primary 1: Predicted and Observed by Mastery Score by Subtest for Grade 3 Students

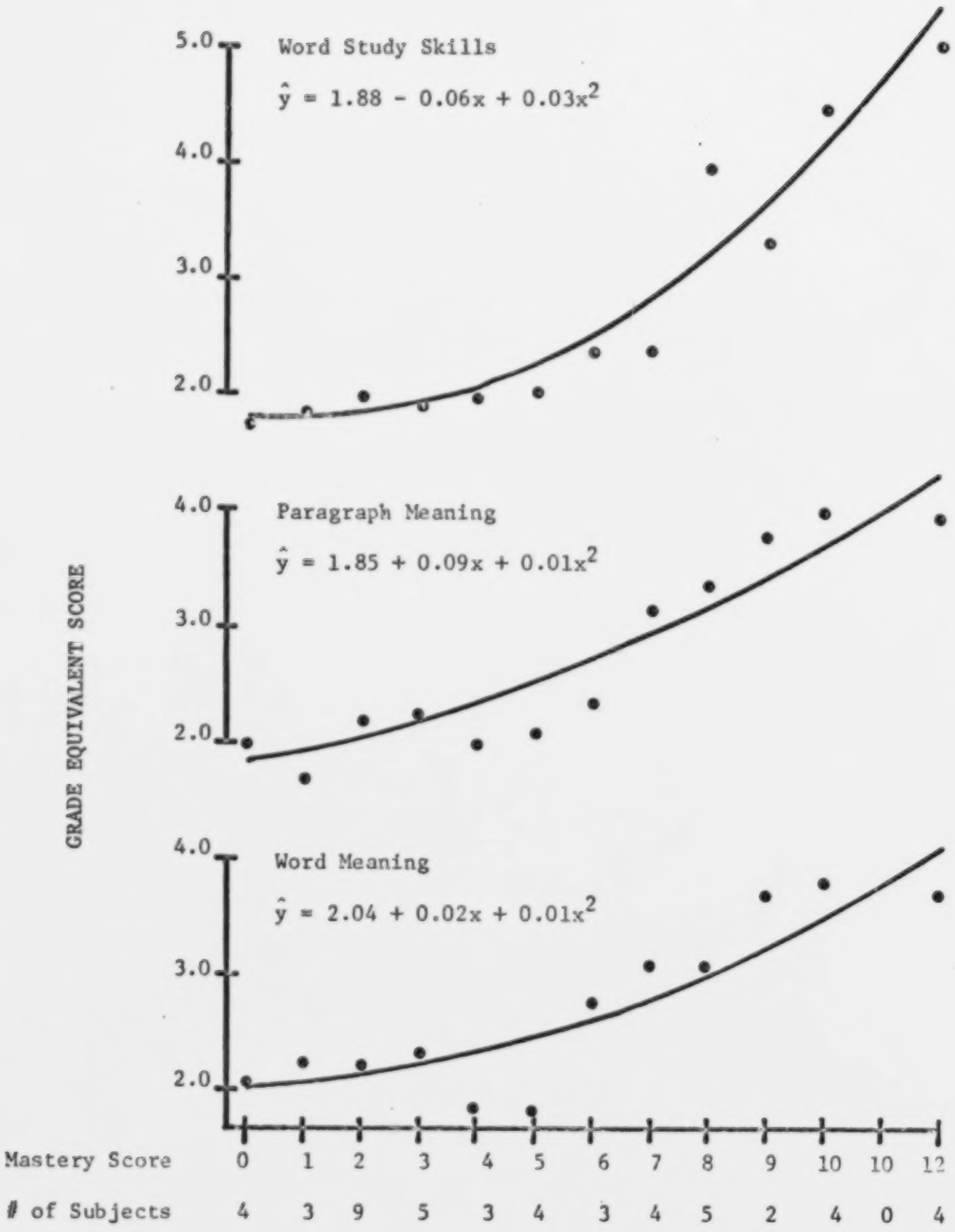
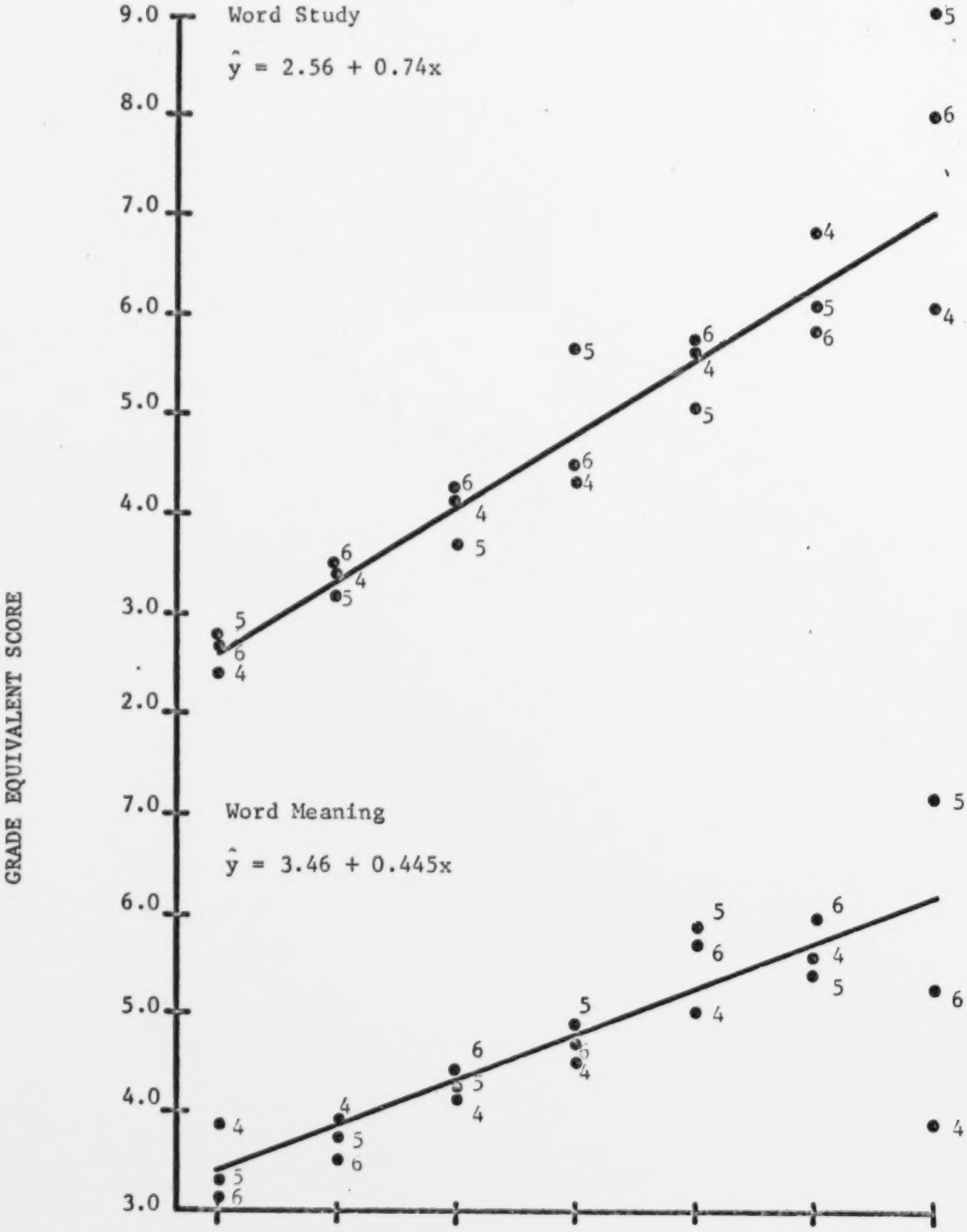


FIGURE 4: Stanford Achievement Test Mean Scores: Predicted and Observed by Mastery Score by Subtest for Grade 3 Students



# of Subjects							
	Gr. 4	18	29	19	9	3	2	1
	Gr. 5	13	12	27	13	10	6	1
	Gr. 6	4	9	14	22	10	4	1

FIGURE 5: Stanford Achievement